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Impact of a full-scale mass casualty exercise on hospital staff and implications for future preparedness – A pre-post study

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ABSTRACT

Study hypothesis: Mass casualty incidents (MCI) can overwhelm hospital capacities. Effective management requires emergency plans and exercises to improve familiarity, confidence, and skills. Scientific evaluation of exercises is crucial to identify their impact, this study hypothesized indirect benefits for all staff from MCI exercises, even non-participants.

Methods: Two prospective, representative, anonymous surveys were conducted among all professional groups before and after a full-scale MCI exercise at Heidelberg University Hospital. Descriptive analyses were conducted for the total sample ($N = 669$). Hierarchical linear regression analyses were performed for the dependent constructs *Familiarity with MCI Plan*, *Familiarity with Alert Process*, *Knowledge of Tasks*, and *Knowledge about Roles and Cooperation*.

Results: The exercise positively influenced knowledge of the MCI plan across all four constructs. Employees in management positions and physicians reported higher scores across all constructs. There appeared to be an overall improvement, suggesting that all employees have benefited. Greater significance was observed for theoretical than for practical knowledge.

Conclusions: There were significant improvements of theoretical and practical knowledge of the MCI plan after an exercise. All employees, including those without exercise participation, appeared to benefit, possibly due to increased awareness and enhanced preparation. However, these results cannot be conclusively attributed to the exercise itself.

1. Introduction

Disaster events such as a mass casualty incident (MCI) are infrequent occurrences [1–3]. In the hospitals affected, this can lead to relatively limited functionality due to capacity overload [4]. The provision of hospital alert and deployment plans is mandatory for handling such complex situations. It is generally assumed that training on the contents, in conjunction with regular exercises, contributes to an enhanced ability to act. The necessity of conducting regular all-hands disaster management exercises was emphasized as a lesson learned from the Great Pandemic to ensure better preparedness for future catastrophes [5]. Exercises designed to train for MCIs have been carried out for many decades [6,7]. Regular practice reveals deficits and improves various skills and the ability to act e.g. in terms of familiarity and confidence can improve [8–10]. Regarding the terrorist attacks in Boston in 2013 and Paris in 2015, it appears that practicing has contributed to better patient care in real-life situations [11–15].

Nevertheless, in a survey of over 7000 German physicians, only 33.9

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% stated that their hospital had taken part in such an exercise [16]. This discrepancy could be attributable to the fact that full-scale exercises in particular are complex to organize and can incur expenses ranging from 10,000–100,000 euros, depending on their size [17]. To further investigate the effectiveness of MCI exercises and justify their implementation, it is essential to scientifically monitor and evaluate the exercises that have been carried out [18]. In their evidence-based report from the early 2000s, Hsu et al. found that precise statements regarding the individual exercise effects are not possible due to a heterogeneous study situation. They therefore recommend that such exercises be better scientifically evaluated in the future [10]. This encompasses the establishment of clearly predefined exercise goals and an objective evaluation method. Otherwise, the opportunity to make the effects of exercises visible and to integrate their results into the planning for future events will be missed [19]. Based on these assumptions, the present study aimed to evaluate the effects of exercise on employees of different professional groups at a large tertiary care university trauma centre. The evaluation used a full-scale MCI exercise with 91 patients through a representative before-and-after survey. Exercises may be beneficial for the organization as a whole because they improve systems, enhance coordination, and strengthen organizational resilience, leading to a more prepared and efficient response environment for everyone. We therefore hypothesized that all personnel benefit indirectly from the organization and execution of an MCI exercise, even if they did not participate. This would then suggest the potential for an MCI exercise to have over-additive effects for the hospital. The survey was designed to evaluate factors which could additionally strengthen the exercise effects, including training, profession, professional experience and leadership function.

2. Methods

The aim of the study was to assess the extent of employees' knowledge regarding the management of a MCI and the effects of a full-scale exercise on their preparation and familiarity with the planned procedures. For this purpose, two prospective, representative, anonymous surveys were conducted among all professional groups at Heidelberg University Hospital (UKHD). The pre-surveys were conducted at a point in time when the employees were not yet aware that an exercise would take place, in order to preserve the "naive" status of the participants. At the time of the pre-survey, it was therefore not yet determined which employees would ultimately participate in the exercise. Consequently, a representative sample of the entire clinic staff was to be surveyed in both the pre- and post-surveys as described in section 2.1. The initial survey (pre-survey) was conducted from June 20 to July 31, 2023. The MCI exercise took place on November 11, 2023. The second survey took place from November 27, 2023, to January 11, 2024.

2.1. Participants and sample size

All adult employees working at the surgical center of the UKHD of every profession with defined tasks during an MCI were eligible to participate in the questionnaire. Exclusion criteria were only a refusal of study participation.

The survey was conducted in the different departments by scheduling appointments during team meetings or regular training events. In detail the following departments were contacted for survey participation: all standard wards, emergency departments, intensive and intermediate care units, radiology, urology, general surgery, heart surgery, vascular surgery, trauma and orthopedic surgery, anesthesiology, surgical and anesthesiological assistants and radiological assistants, doormen, security staff, pastoral care, patient logistics, cleaning services.

The sample size was determined using a statistical calculation for a representative approach. The latter is based on the following variables: an estimated number of max. 5000 employees in the surgical clinic, a confidence level of 95 %. Based on these criteria, a margin of error of 5 % ($n \geq 357$) was achieved for the pre-survey and a margin of error of 6 % ($n \geq 254$) for the post-survey.

$$Sample \frac{z^{\frac{2*p(1-p)}{e2}}}{1+\left(\frac{z2*p(1-p)}{e2*N}\right)}$$

N = population size • e = Margin of error (percentage in decimal form) • z = z-score.

(https://www.surveymonkey.de/mp/sample-size-calculator/ accessed: 12.06.2023)

The survey was administered using the online platform Lime Survey® (https://feedback.sektion-notfallmedizin.de) or, as an alternative, in paper form and was then manually entered into the Lime Survey database. The survey was accessed via a non-personalized hyperlink or QR code. Apart from the occupational group and professional experience, as well as the question about a management function, no data was collected that would enable the identification of an individual (e.g. email address, workplace, etc.). The estimated time required to complete the questionnaire was approximately 10 to 15 min.

2.2. Full-scale mass casualty incident exercise

The exercise was a full-scale mass casualty exercise involving 100 casualties following an explosion in a public building. The exercise began in the pre-hospital setting, followed by the transportation of the patients to the hospital and their admission. The survey focuses on the part of the exercise that took place in hospital. A total of approximately 140 people from various professions within the hospital staff participated in the exercise. The exercise included alerting staff, registering them at the hospital, forming treatment teams, establishing a command structure, receiving and triaging the injured by the emergency services personnel, further treatment in the individual areas according to the triage categories (red, yellow, and green), and performing diagnostics (e.g., ultrasound, X-rays, or CT scans). The process for each patient ended either with transfer to the operating room, to a ward, to another hospital, or with death. In this way, the hospital's mass casualty plan was fully implemented. To preserve realism, neither the scenario nor the scale of the exercise was disclosed in advance; staff were only informed of the date.

2.3. Dependent variables

To assess the key constructs related to disaster preparedness and response at UKHD, four constructs were developed: (1) *Familiarity with the MCI Plan*, (2) *Familiarity with the Alert Process*, (3) *Knowledge of Tasks*, and (4) *Knowledge about Roles and Cooperation*. The first construct, *Familiarity with MCI plan*, reflects the general awareness of the plan's existence, accessibility, content, and associated responsibilities. The latter three constructs, however, capture specific, actionable knowledge related to the alert process, concrete tasks, and interprofessional collaboration during an MCI event. The items used for these variables are shown in Table 1.

It is noteworthy that one construct was measured using both dichotomous and Likert scale items. To ensure consistency and comparability across the different response formats, the Likert scale items (ranging from 1 to 6) were rescaled to a unified range of 0 to 1. Specifically, "Not at all true" was coded as 0, "Mostly not true" as 0.2, "Somewhat not true" as 0.4, "Somewhat true" as 0.6, "Mostly true" as 0.8 and "Completely true" as 1.0. This transformation enabled the aggregation of both scale types on a common scale ranging from 0 to 1, facilitating a unified interpretation of the dependent variables. The specific Cronbach's alpha values - indicating acceptable to good internal consistency - can be found in Table 1.

Table 1
Variables, Response Scales and Reliability of the Four Dependent Constructs.

Construct	Variable	Scale	Cronbach's Alpha
Familiarity with the MCI Plan	I am aware that there is a Mass Casualty Incident (MCI) plan at University Hospital Heidelberg (UKHD). I know how and where to access this MCI plan.	No (0) / Yes (1)	0.86
	I am familiar with the contents of the MCI plan. I know the different actors and their professional responsibilities in the event of a MCI. I am aware of my tasks in such a situation (e.g., actions after an alarm, arrival, items to bring, location to go to, etc.).	Not at all true (0) Mostly not true (0.2) Somewhat not true (0.4) Somewhat true (0.6) Mostly true (0.8) Completely true (1.0)	
Familiarity with the aAlert Process	I know how I will be alerted in the event of a disaster/MCI at UKHD. I am informed about how I should behave during a MCI alert. I know where to report within UKHD during a MCI.	No (0) / Yes (1)	0.84
Knowledge of Tasks	I know the planned spatial arrangement for a MCI at UKHD (e.g., triage, treatment). I am familiar with where to find the necessary materials for my role during a MCI at UKHD. I know the documentation procedures for patients during a MCI.	No (0) / Yes (1)	0.77
Knowledge about Roles and Cooperation	I know with whom I will collaborate during a MCI at UKHD (e.g., team formation). I am aware of who is responsible for MCI tasks in my field/role. I know who has authority over me during a MCI at UKHD. I know who I can talk to about stressful situations after a MCI.	No (0) / Yes (1)	0.80

2.4. Data analysis

Statistical data were exported into an electronic database system (Microsoft Excel®, Microsoft Deutschland GmbH, Unterschleißheim, Germany). The statistical analysis and figures were performed using R Version 4.3.3 (packages base R and tidyverse). The data collected was analyzed using descriptive statistics for the total sample as well as for subgroups based on leadership position, years of professional experience, occupational group, exercise participation, and time of questioning. This was done using absolute and relative frequencies, or their mean and confidence intervals. Missing values were handled using pairwise deletion. To assess whether significant differences exist across these categories, an analysis of variance (ANOVA) was performed. The significance level was set at 5 %. Effect sizes for pairwise comparisons of time and exercise participation were calculated using Cohen's d.

To examine the effects of exercise participation and survey time on *Familiarity with the MCI Plan*, *Familiarity with the alert Process*, *Knowledge of Tasks*, and *Knowledge of Roles and Cooperation*, hierarchical linear regression analyses were conducted for each dependent variable. Predictors were entered into the model in three steps: In the first step, management function (0 = no management function, 1 = management function), years of professional experience (continuous), and occupational group (with physicians as the reference category; nurses and other staff were compared to physicians) were included as control variables.

In the second step, exercise participation (0 = no prior exercise participation, 1 = participation in at least one exercise before 2023 and/or in 2023) was added to examine its unique contribution. The third step involved the incorporation of survey time (0 = pre-survey, 1 = post-survey) to assess whether the dependent variables improved not only for exercise participants but also for individuals present at the hospital during the exercise period.

For each step, F-test values and R^2 values were reported to evaluate model fit. Unstandardized regression coefficients (B), standard errors (SE), 95 % confidence intervals (CI), and significance levels (p) were also reported for each predictor.

2.5. Ethics

The survey was conducted in accordance with the current version of the Declaration of Helsinki. At the beginning of the survey, the respondents were informed that all data collected would be stored anonymously and that they could discontinue participation at any time. The study protocol was positively reviewed by the Ethics Committee of the Medical Faculty of Heidelberg prior to the start of the study (S-294/2023). The study adheres to the guidelines outlined in the STROBE statement [20].

3. Results

3.1. Pre- and post-survey baseline characteristics

A total of 701 questionnaires (pre- and post-survey) were filled out. The final sample comprised 669 participants who had responded to at least one item measuring the dependent variables. Individuals ($n = 31$) who dropped out before reaching the relevant sections of the questionnaire were excluded from the analyses. One additional case was excluded due to the provision of implausible information, specifically the reporting 200 years of professional experience. Of the participants included in the study, 392 completed the pre-survey and 277 completed the post-survey. Among the latter group, 90 individuals reported having completed the preliminary survey.

The final sample comprised 573 individuals who did not hold a management function and 96 who did. The range of reported professional experience was from 0 to 45 years, with a mean of 11.3 years and a standard deviation of 11.2 years. With regard to their professional roles, the sample consisted of 225 physicians, 335 nurses, and 109 other hospital staff members. A total of 142 participants indicated prior participation in a disaster exercise at the hospital, while 527 had not.

3.2. Effects of dependent variables

The results for the total sample indicate that all constructs were evaluated with a mean below 0.5 and the maximum values in the construct of *Familiarity with the MCI Plan* (Mean: 0.47, 95 % CI [0.45, 0.50]) (Table 2). It is noteworthy that the performance for all dependent variables is poorest for *Knowledge of Tasks* for the total sample (Mean: 0.25, 95 % CI [0.23, 0.28]). The evaluation shows that compared to the other participants, those with management functions exhibit significantly ($p < 0.001$) more pronounced knowledge in all four constructs *Familiarity with the MCI Plan*, *Familiarity with the Alert Process*, *Knowledge of Tasks* and *Knowledge About Roles and Cooperation* (Table 2). Belonging

Table 2
Descriptive Statistics and ANOVA Results for Dependent Variables Across Group Categories.

	Familiarity with MCI Plan			Familiarity with Alert Process			Knowledge of Tasks			Knowledge about Roles and Cooperation		
Variable	n	M	95 % CI [LL, UL]	n	M	95 % CI [LL, UL]	n	M	95 % CI [LL, UL]	n	M	95 % CI [LL, UL]
Total sample	669	**0.47**	[0.45, 0.50]	652	**0.44**	[0.41, 0.47]	637	**0.25**	[0.23, 0.28]	637	**0.35**	[0.32, 0.38]
Management function												
No management function	573	**0.45**	[0.42, 0.47]	560	**0.40**	[0.37, 0.44]	547	**0.22**	[0.19, 0.25]	547	**0.32**	[0.29, 0.35]
Management function	96	**0.63**	[0.57, 0.69]	92	**0.68**	[0.61, 0.76]	90	**0.45**	[0.36, 0.53]	90	**0.54**	[0.47, 0.62]
ANOVA results	$F(1,667) = 29.7$, $p < 0.001$***			$F(1,650) = 36.8$, $p < 0.001$***			$F(1,635) = 32.1$, $p < 0.001$***			$F(1,635) = 29.0$, $p < 0.001$***		
Years of professional experience												
0–2 years	166	**0.39**	[0.35, 0.44]	161	**0.40**	[0.33, 0.46]	156	**0.25**	[0.20, 0.31]	156	**0.31**	[0.26, 0.37]
>2–5 years	128	**0.51**	[0.46, 0.56]	125	**0.42**	[0.35, 0.49]	120	**0.26**	[0.20, 0.32]	120	**0.36**	[0.29, 0.42]
>5–15 years	191	**0.52**	[0.48, 0.56]	186	**0.48**	[0.42, 0.54]	183	**0.25**	[0.20, 0.30]	183	**0.38**	[0.33, 0.43]
>15 years	184	**0.48**	[0.43, 0.52]	180	**0.45**	[0.39, 0.51]	178	**0.25**	[0.20, 0.30]	178	**0.34**	[0.29, 0.40]
ANOVA results	$F(3,665) = 5.9$, $p < 0.001$***			$F(3,648) = 1.3$, $p = 0.262$			$F(3,633) = 0.0$, $p = 0.999$			$F(3,633) = 0.9$, $p = 0.438$		
Occupational group												
Physicians	225	**0.58**	[0.55, 0.62]	220	**0.57**	[0.52, 0.63]	212	**0.35**	[0.30, 0.40]	212	**0.48**	[0.43, 0.54]
Nurses	335	**0.41**	[0.38, 0.44]	327	**0.33**	[0.29, 0.37]	322	**0.18**	[0.15, 0.21]	322	**0.24**	[0.21, 0.28]
Other staff members	109	**0.44**	[0.38, 0.51]	105	**0.52**	[0.44, 0.60]	103	**0.29**	[0.22, 0.36]	103	**0.40**	[0.33, 0.48]
ANOVA results	$F(2,666) = 23.4$, $p < 0.001$***			$F(2,649) = 25.2$, $p < 0.001$***			$F(2,634) = 14.7$, $p < 0.001$***			$F(2,634) = 29.6$, $p < 0.001$***		
Exercise participation												
No participation	527	**0.41**	[0.39, 0.43]	511	**0.35**	[0.32, 0.39]	502	**0.18**	[0.16, 0.21]	502	**0.29**	[0.26, 0.32]
Prior participation	142	**0.71**	[0.66, 0.75]	141	**0.75**	[0.70, 0.81]	135	**0.51**	[0.45, 0.58]	135	**0.58**	[0.52, 0.64]
ANOVA results	$F(1,667) = 122$, $p < 0.001$***			$F(1,650) = 113$, $p < 0.001$***			$F(1,635) = 102$, $p < 0.001$***			$F(1,635) = 68.9$, $p < 0.001$***		
Time of questioning												
Pre-survey	392	**0.40**	[0.37, 0.43]	379	**0.36**	[0.32, 0.40]	373	**0.21**	[0.18, 0.24]	373	**0.29**	[0.25, 0.32]
Post-survey	277	**0.57**	[0.54, 0.61]	273	**0.56**	[0.51, 0.60]	264	**0.32**	[0.27, 0.36]	264	**0.44**	[0.39, 0.48]
ANOVA results	$F(1,667) = 55.0$, $p < 0.001$***			$F(1,650) = 35.5$, $p < 0.001$***			$F(1,635) = 14.2$, $p < 0.001$***			$F(1,635) = 24.1$, $p < 0.001$***		

Note. $N = 669$. n = subsample size; M = mean; CI = confidence interval; LL = lower limit; UL = upper limit.

to the professional group of physicians is also associated with significantly higher knowledge in all four constructs ($p < 0.001$) (see Table 2). A significant difference between professional experience groups was found only for Familiarity with the MCI Plan, with participants new to the profession (0–2 years) reporting the lowest mean (0.39, 95 % CI [0.35, 0.44]). The strongest increase in all constructs ($p < 0.001$) were shown for the variable of prior exercise participation, where the mean value (M) was almost double that of participants with no exercise participation (Table 2). Exercise participation thus led to significantly higher scores on all four constructs, with effect sizes (Cohen's d) indicating large effects: $d = 1.04$ for Familiarity with the MCI Plan, $d = 1.01$ for Familiarity with the Alert Process, $d = 0.98$ for Knowledge of Tasks, and $d = 0.81$ for Knowledge About Roles and Cooperation. Similarly, the time of survey (pre vs. post) also had a significant effect on all four constructs ($p < 0.001$, Table 2). Although less pronounced than the exercise participation effect, these results still showed meaningful improvements, with effect sizes corresponding to small to medium effects: $d = 0.58$ for Familiarity with the MCI Plan, $d = 0.47$ for Familiarity with the Alert Process, $d = 0.30$ for Knowledge of Tasks, and $d = 0.40$ for Knowledge About Roles and Cooperation.

3.3. *Comparison of participants regarding the time of questioning and exercise participation*

An analysis of the time of questioning (pre- vs. post) and previous exercise participation reveals that the lowest values in all four constructs occur in the group of participants in the pre-survey with *no prior exercise participation* (Mean: 0.36, 95 % CI [0.33, 0.39], mean: 0.31, 95 % CI [0.27, 0.35], mean; 0.18, CI 95 % [0.15, 0.21], mean: 0.26, 95 % CI [0.22, 0.30]) (Table 3). The highest values were achieved by participants who had either taken part only in the 2023 MCI exercise or in both the 2023 exercise and previous exercises, here the means of all four constructs range between 0.79 (95 % CI [0.70, 0.88], *Knowledge of Tasks*) and 1.00 (95 % CI [1.00, 1.00], *Familiarity with Alert Process*). The mean values for three constructs increased in the post-survey compared to the pre-survey, even when taking into account the group of participants who had *no prior exercise participation*: 0.49 vs. 0.36 (*Familiarity with the MCI Plan*) and 0.43 vs. 0.31 (*Familiarity with the Alert Process)* and 0.33 vs. 0.26 (*Knowledge About Roles and Cooperation*) (see Table 3). However, this does not apply to the *Knowledge of Tasks* construct, where the mean values remained approximately at the same level both in the

Table 3
Descriptive Statistics and ANOVA Results for Time of Questioning and Prior Exercise Participation.

	Familiarity with the MCI Plan			*Familiarity with the Alert Process*			*Knowledge of Tasks*			*Knowledge about Roles and Cooperation*		
Variable	*n*	*M*	95 % CI [LL, UL]	*n*	*M*	95 % CI [LL, UL]	*n*	*M*	95 % CI [LL, UL]	*n*	*M*	95 % CI [LL, UL]
Pre-survey												
No prior exercise participation	328	**0.36**	[0.33, 0.39]	316	**0.31**	[0.27, 0.35]	311	**0.18**	[0.15, 0.21]	311	**0.26**	[0.22, 0.30]
Prior exercise participation (before 2023)	64	**0.62**	[0.54, 0.69]	63	**0.61**	[0.51, 0.71]	62	**0.35**	[0.26, 0.44]	62	**0.43**	[0.34, 0.53]
Post-survey												
No prior exercise participation	199	**0.49**	[0.46, 0.53]	195	**0.43**	[0.37, 0.49]	191	**0.19**	[0.15, 0.23]	191	**0.33**	[0.28, 0.38]
Prior exercise participation (only before 2023)	25	**0.61**	[0.52, 0.70]	25	**0.69**	[0.56, 0.83]	25	**0.33**	[0.19, 0.48]	25	**0.48**	[0.33, 0.63]
First exercise participation in 2023	33	**0.88**	[0.84, 0.92]	33	**0.93**	[0.87, 0.99]	32	**0.79**	[0.70, 0.88]	32	**0.80**	[0.74, 0.87]
Multiple exercises including 2023	20	**0.85**	[0.79, 0.90]	20	**1.00**	[1.00, 1.00]	16	**0.85**	[0.75, 0.96]	16	**0.84**	[0.76, 0.93]
ANOVA results	$F(5,663) = 37.8$, $p < 0.001$***			$F(5,646) = 31.0$, $p < 0.001$***			$F(5,631) = 35.8$, $p < 0.001$***			$F(5,631) = 22.7$, $p < 0.001$***		

Note. $N = 669$. n = subsample size; M = mean; CI = confidence interval; LL = lower limit; UL = upper limit.

pre- and post- comparison of participants who had *no prior exercise participation* 0.18 vs. 0.19 and in the comparison of participants who had only participated in exercises before 2023 (0.35 vs. 0.33). Nevertheless, the absolute values were higher for participants who had participated in exercises in the past than for those who had *no prior exercise participation* at all.

Looking at the mean values of the individual constructs for the different groups in total, the values for the subjects who have never taken part in an exercise have nevertheless increased after the current MCI exercise (Fig. 1). It can also be deduced that subjects who have already taken part in an exercise in the past start with higher initial values in the pre-survey, even if they did not take part in the actual exercise, the values also increased here in the post-survey (Fig. 1). The subjects who took part in the actual exercise had significantly higher summative scores in the post-survey, and this was even more pronounced in the group that had also taken part in previous exercises (see Fig. 1).

The Figure illustrates that the summary of mean values for the constructs rises with more frequent exercising and that actual exercises have more impact especially on Knowledge of Tasks and Roles and Cooperation than past exercises. Nevertheless, also participants without any exercise participation had higher values in the post-survey.

3.4. Stepwise regression of the dependent variables

In order to better quantify the observed effects of the aforementioned dependent variables, these are shown for each construct in a hierarchical regression (Table 4–7). The results show that across all four constructs, the participants' *professional experience* only had an effect for *Familiarity with the MCI Plan* ($p = 0.023$) *and Familiarity with the Alert Process* ($p = 0.044$) (Tables 4 & 5). However, there were significant differences between the professional groups, always in relation to the group of physicians. The unstandardized regression weights of the nursing staff were significantly lower in all categories, whereas the other occupational groups cumulatively only performed significantly differently especially in the construct *Familiarity with MCI Plan* ($p < 0.001$) (Table 2). Otherwise, there were no significant differences to the physicians for the other three constructs. Interestingly, the effects between nurses and physicians are least pronounced in the construct *Knowledge of Tasks (Nurses: -0.14, SE 0.03, 95 % CI [−0.21,-0.08] (Step 1 in* Table 6*)*.

The addition of the dependent variable *exercise participation* in Step 2 increases the variance explanation R^2 in all constructs. *Familiarity with MCI Plan* and *Familiarity with Alert Process* almost doubles ($\Delta R^2 = 0.101$ and $\Delta R^2 = 0.091$). However, the greatest effect of *exercise participation* was once again evident in the *Knowledge of Tasks* construct, where the variance explanation in Step 1 was the lowest among all four constructs ($R^2 = 0.084$). However, the exercise effect more than doubled it ($R^2 = 0.182$) (see Table 6). In Step 3, the time of questioning (pre- vs. post -)

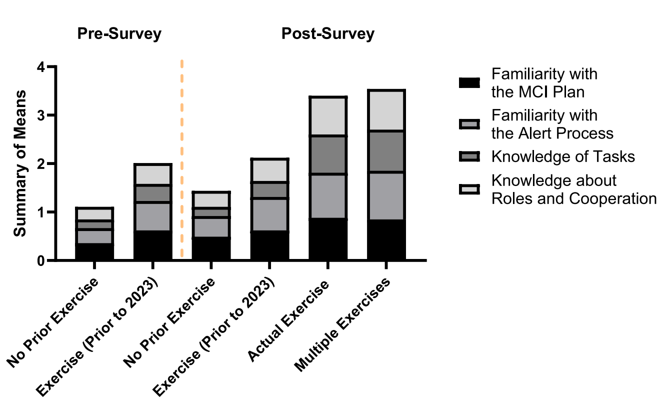

Fig. 1. Rising Means in the four Constructs for the different Participant Groups in order to Exercise Participation.

was examined, with an observable effect noted across all four constructs (R^2 + 0.053, +0.037, +0.012, +0.027), although this was again least pronounced in the practical constructs: *Knowledge of Tasks* and *Knowledge About Roles and Cooperation* compared to the others. Taken together, it becomes apparent that employment in the hospital alone during the period of the exercise can have a positive effect on knowledge of the MCI plan regarding all four constructs, extending beyond participation in the exercise. However, this effect varies and is more pronounced regarding theoretical knowledge (*Familiarity with MCI Plan* and *Alert Process*) than for practical issues (*Knowledge of Tasks and Knowledge About Roles and Cooperation)*, in the event of a MCI. Of the total sample, 90 participants completed both the preliminary and post-intervention surveys, which could potentially confound the results. To address this, regression analyses from Step 3 were repeated, with these 90 individuals excluded from the post-survey dataset, thereby ensuring the statistical independence of the pre- and post-survey samples. This procedure permitted an examination of whether overlapping participants influenced the main effects of time and exercise intervention. The unstandardized regression coefficients and significance levels of the main effects for the four dependent constructs were as follows: Familiarity with MCI Plan – Total sample: Exercise participation $B = 0.22$, $p < 0.001$ ***; Time of questioning $B = 0.15$, $p < 0.001$ ***. Post-survey sample excluding respondents who had also completed the pre-survey: Exercise participation $B = 0.23$, $p < 0.001$ ***; Time of questioning $B = 0.12$, $p < 0.001$ ***. Familiarity with Alert Process – Total sample: Exercise participation $B = 0.30$, $p < 0.001$ ***; Time of questioning $B = 0.17$, $p < 0.001$ ***. Post-survey sample excluding respondents who had also completed the pre-survey: Exercise participation $B = 0.27$, $p < 0.001$ ***; Time of questioning $B = 0.13$, $p < 0.001$ ***. Knowledge of Tasks – Total sample: Exercise participation $B = 0.27$, $p < 0.001$ ***; Time of questioning $B = 0.08$, $p = 0.002$ **. Post-survey sample excluding respondents who had also completed the pre-survey: Exercise participation $B = 0.23$, $p < 0.001$ ***; Time of questioning $B = 0.06$, $p = 0.051$. Knowledge About Roles and Cooperation – Total sample: Exercise participation $B = 0.20$, $p < 0.001$ ***; Time of questioning $B = 0.13$, $p < 0.001$ ***. Post-survey sample excluding respondents who had also completed the pre-survey: Exercise participation $B = 0.20$, $p < 0.001$ ***; Time of questioning $B = 0.12$, $p < 0.001$ ***.

Overall, the main effects remained robust. In some cases, the regression weights decreased slightly, which is unsurprising given the reduced sample size. Only for Knowledge of Tasks did the effect of time become marginally significant ($p = 0.051$) after the reduction in sample size, with the regression weight decreasing slightly from 0.08 to 0.06.

4. Discussion

In this study, a representative before and after survey was conducted among the employees of the UKHD, Germany, at the surgical center in conjunction with a full-scale MCI exercise. The findings indicate that exercises have a positive effect on different components of knowledge and skills in relation to the MCI plan.

In addition to the positive effects of participating in the exercise, there appeared to be an overall improvement, suggesting that even employees who did not directly participate in the exercise might have benefited indirectly. The implementation of a full-scale MCI exercise may be associated with 'over-additive effects', in that not only participants but also other employees present in the hospital during the exercise might benefit. However, these results cannot be conclusively attributed to the exercise itself. The positive effects of previous exercises were still noticeable, but the greatest benefits became apparent after the most recent participation in the exercises. At the same time, improvements in the practical implementation of the MCI plan (*Knowledge of Tasks*) were particularly enhanced for participants of a recent exercise. Professional experience had little influence on knowledge of the individual constructs. However, it was found that employees in management positions and physicians had better knowledge about the components of

Table 4
Hierarchical Regression Results for Familiarity with MCI Plan.

Step	Variable	B	*SE*	95 % CI [LL, UL]	*p*	R^2	Overall Model Significance (*F, p*)
Step 1	Management function[a]	0.14	0.03	[0.07,0.21]	<0.001 ***	0.105	F(4,664) = 19.51
	Years of professional experience [b]	0.03	0.01	[0.00,0.05]	0.023 *		p < 0.001 ***
	Occupational group [c]						
	Nurses	−0.18	0.03	[−0.23,−0.13]	<0.001 ***		
	Other staff members	-0.13	0.03	[−0.20,-0.07]	<0.001 ***		
Step 2	Management function[a]	0.09	0.03	[0.03,0.15]	0.006 **	0.206	F(5,663) = 34.33
	Years of professional experience [b]	0.01	0.01	[−0.01,0.04]	0.251		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.14	0.03	[−0.19,-0.09]	<0.001 ***		
	Other staff members	−0.11	0.03	[−0.17,-0.05]	<0.001 ***		
	Exercise participation[d]	0.25	0.03	[0.20,0.30]	<0.001 ***		
Step 3	Management function[a]	0.11	0.03	[0.05,0.17]	<0.001 ***	0.259	F(6,662) = 38.48
	Years of professional experience [b]	0.02	0.01	[−0.01,0.04]	0.159		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.14	0.02	[−0.18,-0.09]	<0.001 ***		
	Other staff members	−0.10	0.03	[−0.16,-0.03]	0.002 **		
	Exercise participation[d]	0.22	0.03	[0.17,0.27]	<0.001 ***		
	Time of questioning[e]	0.15	0.02	[0.10,0.19]	<0.001 ***		

Note. N = 669. B = unstandardized regression weights; *SE* = standard error; CI = confidence interval; LL = lower limit; UL = upper limit.
[a] 0 = no management function, 1 = management function.
[b] z-standardized.
[c] The occupational groups were compared with the group "physician".
[d] 0 = no exercise participation, 1 = participation in at least one exercise (before 2023 and/or in 2023).
[e] 0 = pre-survey, 1 = post-survey.

Table 5
Hierarchical Regression Results for Familiarity with Alert Process.

Step	Variable	B	*SE*	95 % CI [LL, UL]	*p*	R^2	Overall Model Significance (*F, p*)
Step 1	Management function[a]	0.23	0.05	[0.14,0.32]	<0.001 ***	0.121	F(4,647) = 22.25
	Years of professional experience [b]	0.03	0.02	[0.00,0.07]	0.044 *		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.24	0.04	[−0.32,-0.17]	<0.001 ***		
	Other staff members	−0.04	0.05	[−0.13,0.06]	0.426		
Step 2	Management function[a]	0.16	0.05	[0.07,0.25]	<0.001 ***	0.212	F(5,646) = 34.78
	Years of professional experience [b]	0.02	0.02	[−0.02,0.05]	0.353		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.19	0.04	[−0.26,-0.12]	<0.001 ***		
	Other staff members	−0.01	0.05	[−0.10,0.08]	0.866		
	Exercise participation[d]	0.33	0.04	[0.25,0.40]	<0.001 ***		
Step 3	Management function[a]	0.18	0.04	[0.09,0.27]	<0.001 ***	0.249	F(6,645) = 35.56
	Years of professional experience [b]	0.02	0.02	[−0.01,0.05]	0.257		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.19	0.03	[−0.25,-0.12]	<0.001 ***		
	Other staff members	0.01	0.04	[−0.08,0.09]	0.872		
	Exercise participation[d]	0.30	0.04	[0.22,0.37]	<0.001 ***		
	Time of questioning[e]	0.17	0.03	[0.11,0.23]	<0.001 ***		

Note. *N* = 652. B = unstandardized regression weights; SE = standard error; CI = confidence interval; LL = lower limit; UL = upper limit.
[a] 0 = no management function, 1 = management function.
[b] z-standardized.
[c] The occupational groups were compared with the group "physician".
[d] 0 = no exercise participation, 1 = participation in at least one exercise (before 2023 and/or in 2023).
[e] 0 = pre-survey, 1 = post-survey.

the MCI Plan.

4.1. Evaluation of MCI exercises

The positive effects of MCI exercises have been demonstrated several times, yet there are only a few evaluations of full-scale MCI exercises carried out in hospital environments (e.g, reports from Bentley et al. or Watkins et al. [21,22]). Positive learning effects for a disaster exercise were demonstrated by Bartley et al. in 2006 based on an MCI exercise with 50 participants in a hospital [23]. A systematic review of 28 full-scale MCI exercises in hospitals published in 2024 confirms this finding [24]. The literature reveals substantial variations across different studies regarding the following metrics: scenario, duration, number of participants, and evaluation methods [24].

In the evaluation of exercises conducted in hospitals, the institutions as a whole were typically the focus, with less emphasis placed on the employees' increase in knowledge or skills [25].To enhance overall hospital preparedness and coordination, involving personnel from various departments and roles in the exercise was notably efficacious according to a study by Watkins et al. [22]. In the present analysis of an interprofessional MCI exercise, cumulative positive effects were consistently found among the exercise participants across different professional groups. The results of the present study are in line with those of a survey of 104 employees, which was conducted after the last

Table 6
Hierarchical Regression Results for Knowledge of Tasks.

Step	Variable	B	*SE*	95 % CI [LL, UL]	*p*	R^2	Overall Model Significance (*F*, *p*)
Step 1	Management function[a]	0.21	0.04	[0.13,0.29]	<0.001 ***	0.084	F(4,632) = 14.57
	Years of professional experience[b]	−0.01	0.01	[−0.04,0.02]	0.635		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.14	0.03	[−0.21,-0.08]	<0.001 ***		
	Other staff members	−0.04	0.04	[−0.12,0.05]	0.389		
Step 2	Management function[a]	0.15	0.04	[0.08,0.23]	<0.001 ***	0.182	F(5,631) = 28.05
	Years of professional experience[b]	−0.02	0.01	[−0.05,0.00]	0.079		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.09	0.03	[−0.15,-0.03]	0.003 **		
	Other staff members	−0.01	0.04	[−0.09,0.07]	0.844		
	Exercise participation[d]	0.29	0.03	[0.22,0.35]	<0.001 ***		
Step 3	Management function[a]	0.16	0.04	[0.09,0.24]	<0.001 ***	0.194	F(6,630) = 25.28
	Years of professional experience [b]	−0.02	0.01	[−0.05,0.00]	0.092		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.09	0.03	[−0.15,-0.03]	0.003 **		
	Other staff members	0.00	0.04	[−0.08,0.08]	0.984		
	Exercise participation[d]	0.27	0.03	[0.21,0.34]	<0.001 ***		
	Time of questioning[e]	0.08	0.03	[0.03,0.13]	0.002 **		

Note. *N* = 637. B = unstandardized regression weights; SE = standard error; CI = confidence interval; LL = lower limit; UL = upper limit.
[a] 0 = no management function, 1 = management function.
[b] z-standardized.
[c] The occupational groups were compared with the group “physician”.
[d] 0 = no exercise participation, 1 = participation in at least one exercise (before 2023 and/or in 2023).
[e] 0 = pre-survey, 1 = post-survey.

Table 7
Hierarchical Regression Results for Knowledge About Roles and Cooperation.

Step	Variable	B	*SE*	95 % CI [LL, UL]	*p*	R^2	Overall Model Significance (*F*, *p*)
Step 1	Management function[a]	0.19	0.04	[0.11,0.27]	<0.001 ***	0.118	F(4,632) = 21.22
	Years of professional experience [b]	0.01	0.02	[−0.02,0.04]	0.519		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.23	0.03	[−0.30,-0.17]	<0.001 ***		
	Other staff members	−0.07	0.04	[−0.15,0.02]	0.114		
Step 2	Management function[a]	0.14	0.04	[0.06,0.22]	<0.001 ***	0.173	F(5,631) = 26.48
	Years of professional experience [b]	0.00	0.01	[−0.03,0.02]	0.775		*p* < 0.001 ***
	Occupational group[c]						
	Nurses	−0.19	0.03	[−0.26,-0.13]	<0.001 ***		
	Other staff members	−0.05	0.04	[−0.13,0.04]	0.274		
	Exercise participation[d]	0.23	0.04	[0.16,0.30]	<0.001 ***		
Step 3	Management function[a]	0.16	0.04	[0.08,0.24]	<0.001 ***	0.200	F(6,630) = 26.28
	Years of professional experience [b]	0.00	0.01	[−0.03,0.03]	0.871		p < 0.001 ***
	Occupational group[c]						
	Nurses	−0.19	0.03	[−0.25,-0.13]	<0.001 ***		
	Other staff members	−0.03	0.04	[−0.12,0.05]	0.399		
	Exercise participation[d]	0.20	0.04	[0.14,0.27]	<0.001 ***		
	Time of questioning[e]	0.13	0.03	[0.07,0.18]	<0.001 ***		

Note. N = 637. B = unstandardized regression weights; SE = standard error; CI = confidence interval; LL = lower limit; UL = upper limit.
[a] 0 = no management function, 1 = management function.
[b] z-standardized.
[c] The occupational groups were compared with the group “physician”.
[d] 0 = no exercise participation, 1 = participation in at least one exercise (before 2023 and/or in 2023).
[e] 0 = pre-survey, 1 = post-survey.

MCI full-scale exercise at the UKHD in 2017. Here too, theoretical knowledge of the content and scope (36 % of physicians and 38 % of nursing staff) was higher than practical knowledge of the procedures (28 % of physicians and 29 % of nursing staff) [26]. No influence of professional experience was found in the 2017 survey either [26]. The results of the 2017 survey are similar to the pre-survey results of the present study for participants who have never taken part in an exercise. However, they are significantly lower than the level of knowledge in the pre-survey for employees who had previously taken part in an exercise, where an average of 61–62 % was achieved for the theoretical constructs (*Familiarity with MCI Plan* and *Familiarity with Alert Process)* and 35–41 % for the practical constructs (*Knowledge of Tasks* and *Knowledge About Roles and Cooperation)* (see Table 3).

4.2. Significance of regular training and exercise

While evidence is limited regarding the long-term effects of emergency preparedness exercises, a few studies have been able to show an impact on individual or organizational preparedness over time. In military medicine, advancements and experiences made during wartime are often lost due to post-war cuts, inadequate planning, and failure to incorporate lessons into future training and doctrine, a phenomenon commonly known as the “Walker dip,” which emphasizes the significance of regular training and exercise [27]. The present results provide additional information that prior practice can positively influence knowledge of the MCI plan in the long term (>5 Years) [28]. However, it is noticeable that the practical skills (*Knowledge of Tasks* and *Knowledge About Roles and Cooperation*) in particular are dependent on regular training and are the first to be lost again (see Table 3). Mere exposure to the hospital environment during the exercise appears insufficient to support the acquisition of these skills. This aligns with established theories of knowledge acquisition, which distinguish between declarative knowledge ("knowing that"), which can be gained through information, and procedural knowledge ("knowing how"), which requires repeated practice to refine skills and internalize procedures effectively [29]. Consequently, tabletop exercises are not sufficient to train these skills or to detect limitations in the MCI plan [30]. Furthermore, a single exercise is not enough; skills must be reinforced through multiple, repeated training sessions.

This observation aligns with previous findings that highlight the value of multiple simulations for continuous improvement and learning reinforcement [31]. The present study established that the effects of previous exercises, particularly regarding theoretical knowledge on MCI plan, were retained over a longer period of time. Still, no additive effects from participation in several exercises could be shown. It must be stated that the study was not designed for this purpose and therefore only $n = 20$ of the study participants had already taken part in more than one full-scale MCI exercise.

Another study based on mixed methods was able to show that an exercise carried out shortly before the event positively impacted the ability to cope with the real event. Additionally, there were over-additive effects in that employees provided support to staff who did not take part in exercises [32]. Combined with the results of the present before-and-after survey, which also showed positive effects for employees who did not take part in the exercise, an emergency preparedness exercise could make a significant contribution to coping with real events in this respect through over-additive effects.

The finding that overall employees may benefit from the exercise in addition to the exercise participants is important for those carrying out the exercise, both from an economic and an exercise impact perspective. In practice, this could provide information for both the size and the frequency of exercises. The observed effect can presumably be explained by increased attention to the topic in advance of the MCI exercise, on the one hand due to the media impact and on the other hand due to awareness in the individual departments preparing for a potential exercise.

Further exercises are particularly relevant for understanding the limitations of the MCI plan. Previous studies have shown that exercise participants felt better prepared and were better able to cope with the limitations of the given plans [32]. The present work shows that full-scale emergency preparedness exercises in particular could strengthen knowledge of roles and processes, the latter are therefore essential to increase the adaptive capacity of staff [33]. According to the definition by Engle, this can generally be defined as follows: *'Adaptive capacity is a latent property of an individual, community, or socioecological system, which is activated in response to a crisis or opportunity'* [34]. In contrast to previous studies, however, the present study suggests that positive effects of awareness regarding the MCI plan among the employees of a university hospital can be achieved. The extent to which this is purely factual knowledge or whether this also has positive effects at the action level could be the subject of future studies.

4.3. Limitations

The present study is subject to several important limitations, both in terms of the development and measurement of the constructs, and with regard to issues concerning the data collection process.

Initially, the transformation of Likert scale items into a unified range of 0 to 1, whilst enabling aggregation with dichotomous items, may have resulted in the oversimplification of the data. Furthermore, reliance on self-reported data introduces the potential for social desirability bias, where respondents may overestimate their preparedness or provide answers that align with perceived expectations. Additionally, because the scale only captures knowledge and self-perceived competence, it does not allow assessment of actual performance or skill transfer. Incorporating objective performance measures could help mitigate social desirability bias and provide more reliable data, particularly by enabling a demonstration of actual training effectiveness. The generalizability of the findings is further limited to similar large, university-based tertiary care settings due to the specific context of the MCI plan, alert procedures, and staff roles at UKHD. Cross-institutional studies would help improve the generalizability of findings, allowing for comparisons between different healthcare settings.

A notable limitation pertains to the challenge of aligning pre- and post-survey data and the partial overlap between the two samples. Ninety participants completed both surveys, which could have introduced dependence and potentially confounded the results. To address this, we re-ran the Step 3 regressions after removing these overlapping participants from the post-survey sample, ensuring fully independent groups. This analysis confirmed that the main effects of time and exercise participation remained robust, suggesting that the inclusion of overlapping participants did not meaningfully influence the results. Nonetheless, the inability to link individual responses limits the tracking of individual-level changes and the precision of longitudinal inferences. To strengthen longitudinal analysis, future studies should implement mechanisms to match pre- and post-survey data more accurately.

4.4. Conclusion and directions for future research

The representative and large-scale before and after evaluation of employees at UKHD, Germany, with $n = 672$ participants around a full-scale MCI exercise showed that the employees reported significantly better scores in all the constructs, regardless of whether they had taken part in the exercise.

This indicates a beneficial effect for the organization as a whole. Participation in the exercise significantly improved knowledge of tasks and practical procedures in particular. Further an overall improvement was observed, which may indicate that employees who did not participate in the exercise could also have experienced some benefit and reported an improvement in the constructs of the MCI plan after the exercise. These findings support the moderate evidence that emergency preparedness exercises in hospitals are a useful training measure whose effects may go beyond what has been assumed to date and can offer over-additive effects. For future research, it would be valuable to investigate how the observed effects on non-participants translate into enhanced practical performance and improved coping strategies during actual mass casualty incidents. A further goal could be to determine whether similar effects can also be observed when an unannounced exercise takes place on an ad-hoc basis. While this study addresses disaster management capabilities at the operational level, it would also be valuable to strengthen the empirical foundation at the structural and strategic levels—for example, by evaluating the effectiveness of the incident command system framework—as these levels are crucial for coordination, resource allocation, and decision-making during complex emergencies, including mass casualty incidents (MCIs) [35].

CRediT authorship contribution statement

Maik von der Forst: Writing – review & editing, Writing – original draft, Visualization, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Barbara J. Germann:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Hanne Schaefer:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Data curation, Conceptualization. **Gabriel A. Salg:** Writing – review & editing, Investigation, Data curation. **Markus A. Weigand:** Writing –

review & editing, Supervision, Resources. **Felix C.F. Schmitt:** Writing – review & editing. **Maximilian Dietrich:** Writing – review & editing, Investigation. **Stefan Mohr:** Writing – review & editing, Resources. **Janna Küllenberg:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Markus Ries:** Writing – review & editing, Writing – original draft, Investigation. **Erik Popp:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Conceptualization.

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Declaration of competing interest

None.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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